

Mass Production of High Purity Niobium

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1. Introduction :

High purity niobium is required as a mass-production material for application in superconducting HF accelerator projects worldwide. The paper will review various aspects of this topic. Niobium cannot be considered a rare metal, but deposits of niobium ores with the low tantalum contents required in HF superconductivity applications are very limited and have to be carefully selected and the different ore refining processes have to be critically looked at. Furthermore, worldwide capacities for electron beam melting have to be considered. Various production processes for forming and fabricating the mill products of niobium have been critically examined during the last years. Extrusion and rolling of seamless niobium tubes for the subsequent hydroforming to seamless cavities appears to be an attractive alternative to the established process of deep drawing or spinning rolled sheets.

2. Present Consumption of Niobium and expected Demands for Future Projects

Some planned big Nb projects are asking us, the institutes and the industry, if there will be enough Nb metal and production capacity available to fit the expected time frame for these projects.

At the present there is a yearly consumption of about 400 – 500 t of Nb metal, to be used mostly in alloys, such as Nb1%Zr for the lighting industry and NbTi for superconducting cables for magnets. Only a small proportion of about 1 – 10 t, depending on the numbers of RF SC projects, is used for the production of high RRR applications.

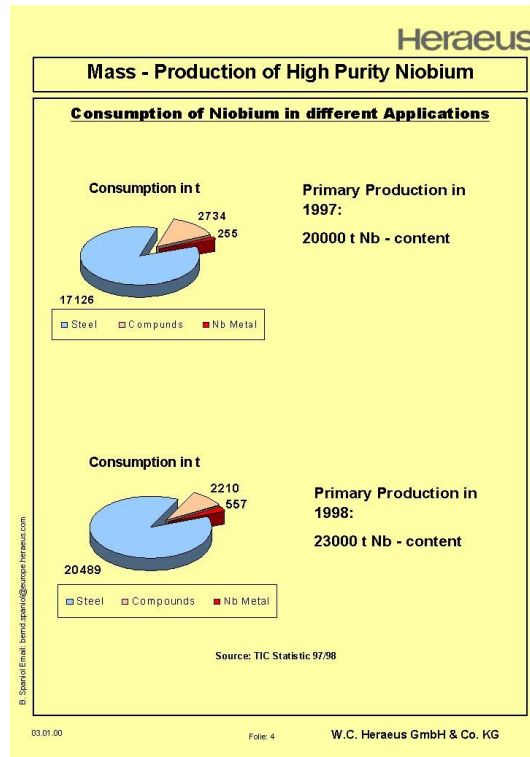
The demands of the future will increase significantly if the TESLA linear collider and several Neutron Spallation Sources will be built. Also the usage of NbTi for the SC cables for LHC will have an influence on the Nb metal market.

Then the total consumption will increase to approximately 650 t of Nb Metal.

Will that increase of more than 50 % bring us to a Nb metal shortage?

Picture 1 shows the Nb production data of the years 1997 and 1998. Only 1 to 2 % of the yearly ore production is used for pure Nb metal.

So in principle there is no danger of a shortage in Nb.



Picture 1 Niobium Consumption [1]

3. Limiting Factors and Refining Processes

The limiting factor is the Ta content, which is even further enriched during the several EB melting cycles so the starting material for the refining by melting should be a specific Nb grade with low Ta content

The Ta content of standard purity Nb can be up to 2000 µg/g and for alloys, e.g. Nb1%Zr, up to 5000 µg/g.

The experience of the last years, when the required RRR values increased from 150 to more than 300, shows that a Nb quality with less than 500 µg/g should be used.

So the purification process from the ore to the melted metal is an important area to look at.

Due to the requirements of the lighting industry and SC cable industry the standard purification process ends with Ta contents of 500 to 5000 µg/g.

However the solvent extraction process with MIBK* or MIPK** can theoretically achieve contents down to 20 µg/g.

Ta contents of 100 to 200 µg/g can be reached under industrial circumstances. If these specific grades would be required in quantities of hundreds of t a year, the expertise and the capacity to produce them are available.

4. Melting Capacity and Production Ways

To our knowledge there are 4 qualified suppliers worldwide for the production of high RRR semi products. But is that available melting capacity sufficient to fit the enlarged demand, if the bigger SC projects are built? To answer that question some more detailed requirements must be specified:

Requirement to be defined

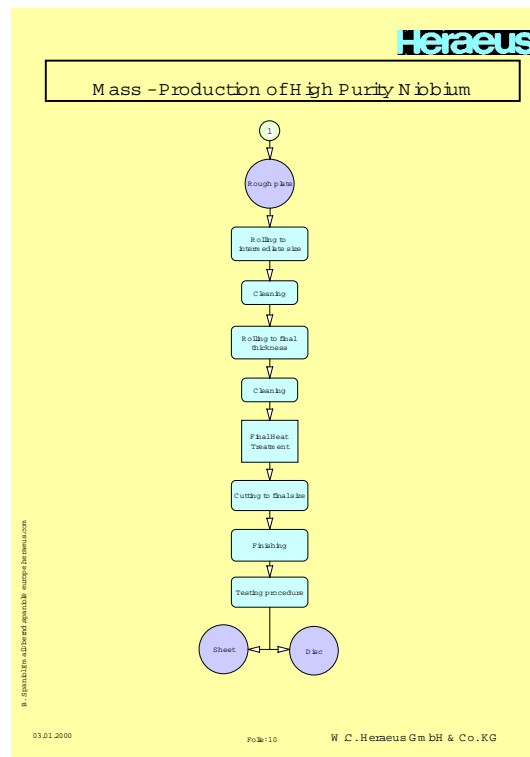
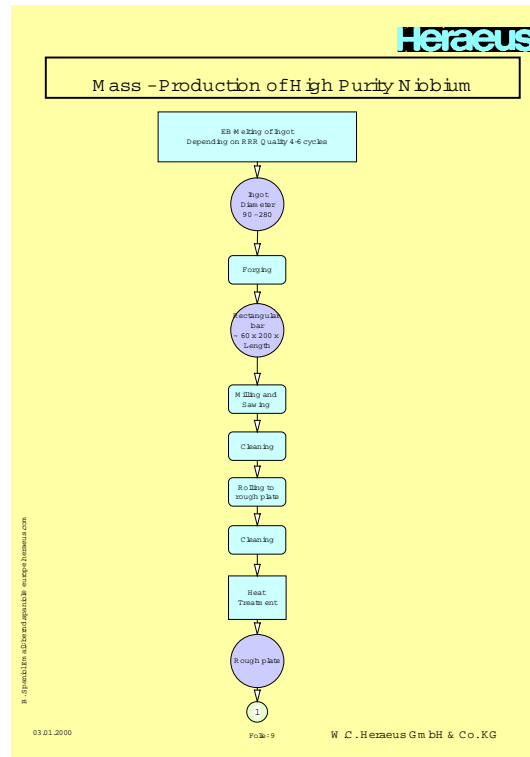
- the RRR value
will it be RRR 250, RRR 300 or RRR 400 or even RRR 600 which will be developed first?
the melting time will increase exponentially with the RRR value
possibly, new furnaces with improved vacuum systems and bigger crucible diameter has to be constructed.
- what kind of semi product will be used to build the cavities?
tubes to build the cavities by hydroforming, or spinning or explosive forming?
sheets to build the cavities by deep drawing and welding?
- what will be the treatment?
starting with very high RRR 500 or more
or Titanisation of the cavity?
- what surface finish will be required?
- what testing procedure will be required?
e.g. scanning with squids, eddy current methods?

This questionnaire shows the open points for a mass production seen from our view point as a semi-product supplier.

Similar questions may be asked of the cavity producers. An early clear statement is recommended, especially with respect to the necessary investments.

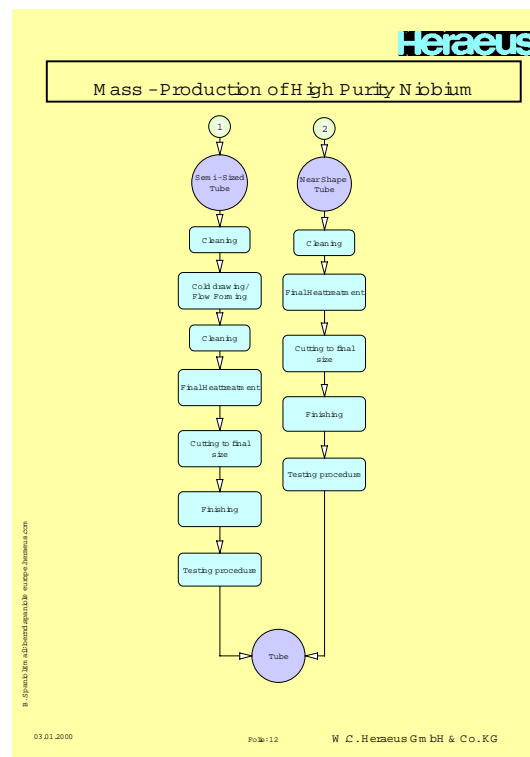
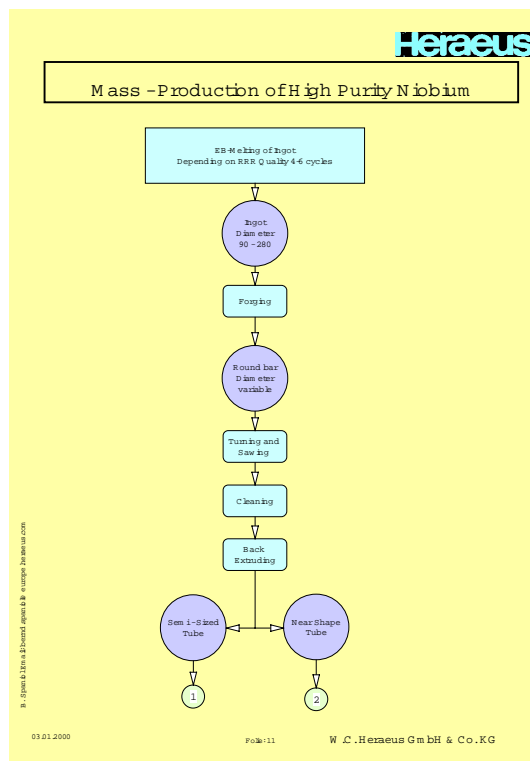
One of the open questions is the production way
For the mass production of Nb semi-products there are two possible production ways.

The well known “sheet” process, see Picture 2,



Picture 2 : Sheet Production Steps

and the “big” seamless Nb tubes process for the direct cavity production by hydroforming or spinning.
For smaller Nb tubes the production steps are the following: see Picture 3



Picture 3 : Tube Production Steps

For “bigger” tubes , e.g. OD 138 x ID 130 x length of 800 to 2000 mm, as would be necessary for the hydroforming of 1.3 GHz TESLA cavities, some changes may be necessary relative to the small tube procedure.

At the moment we are producing 8 seamless tubes for 1:1scale hydroforming trials at DESY

To compare both production ways, you have to see the different numbers of production steps. Additionally to the steps shown in Picture 2 and 3 please bear in mind that e.g. the rolling step includes many individual rolling cycles. However the back extrusion process is a single step.

So the production time for a big tube is significantly lower than for the numbers of sheets which would be needed to build the same cavity.

Also the cavity production from the tubes instead from the sheets will save time.

Picture 4 shows the advantages and disadvantages of both production ways.

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Comparison: Sheet versus Tube Production		
Advantage (+) / Disatvantage (-)		
Criteria	Sheet	Tube
Well known production way for Niobium	++	+-
Factor Input material to Output material	--	--
Numbers of production steps	--	++
Risc of contamination	--	++
Latent energy for recrystallization to „fine“ grain size	+-	+-
Variation in thickness to compensate the Lorentz forces	--	++
Production time to semi product	+-	++
Production time to Cavity	+-	++
Cost to build the cavity	+-	++

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Picture 4: Comparison Sheet vs Tube

The sheet production is well known, the big tube production has to be further developed from the prototype status to an established production way.

The yields from the sheet and the tube production way are strongly dependent on the sizes to be produced. For tubes it can be summarized by an easy formula:

The longer the tube, the better the yield.

As a result of the lower number of production steps and the reduced welding the danger of contamination is significantly lower in the tube production process.

With both processes grain sizes equal to or finer than ASTM 5 can be achieved.

When forming a tube by spinning or flow forming from a thick walled intermediate sized pretube, it is even possible to achieve variations in the wall thickness over the length to compensate the different “LORENTZ” forces in the cavity, so that stiffening rings may be eliminated.

This comparison is valid for the mass production of Nb RRR semi-products,

The mass production of tubes will provide the opportunity to remove the “question marks” still existing in the process. The individual high tooling costs will be minimized by producing large numbers of tubes with the same dimensions.

5. References

- [1] Source : TIC
- * Methylisobutylketon
- ** Methylisophosphylketon

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